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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

FENG CHEN

Serial No. 10/661,019 (TI-35765)

Filed: September 12, 2003

CERTIFICATE OF MAILING OR TRANSMISSION UNDER 37 CFR 1.8

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9-15-04

Jay M. Cantor, Reg. No. 19,906

For: SIGMA-DELTA MODULATOR WITH PASSIVE BANDPASS LOOP FILTER

Art Unit 2819

Examiner Peguy JeanPierre

Customer No. 23494

DECLARATION UNDER 37 C.F.R. 1.131

Director of the United States
Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

JAY M. CANTOR declares as follows:

THAT he has reviewed the patent submission of Feng Chen to the Texas Instruments Patent Department, a copy of which is attached hereto..

THAT on information and belief, the invention disclosed and claimed in the subject patent application is contained in the attached patent submission in a manner ready for patenting under the requirements as set forth in the Supreme Court decision in Pfaff v. Wells Electronics, 525 U.S. 55, 119 S. Ct. 304, 142 L. Ed. 2d 261, 48 U.S.P.Q. 2d 1641.

THAT the attached patent submission was received in the Texas Instruments Patent Department prior to May 1, 2003.

I declare under penalty of perjury that the above statements are true based upon information and belief.

Respectfully submitted,

Jay M. Cantor
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Texas Instruments Incorporated
P.O. Box 655474, M/S 3999
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TI-35765

1600
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Texas Instruments Invention Disclosure Form

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* IF ELECTRONICALLY TRANSMITTED, PROCESSING OF YOUR DISCLOSURE *
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* DATED BY ALL INVENTORS AND AT LEAST ONE WITNESS. *
****

1. Please suggest a descriptive title for your invention:

A Passive Bandpass Sigma Delta Modulator

2. This invention supports which TI priorities: (check all that apply)

(X) Mixed Signal & Logic Products (MSLP)
( ) Application Specific Products (ASP)
( ) Education & Productivity Solutions
(X) Wireless ( ) DLP
( ) Sensors & Controls
( ) Fab/Processes (Make)

MSLP:
( ) Advanced Analog Products (AAP)
( ) Digital Audio/Video (DAV)
( ) Standard Linear & Logic (SLL)
( ) Storage Products (SPG)
( ) Mixed Signal Products (MSP)
( ) Display Solutions (DSBU)
( ) Military Products

ASP:
( ) DSP ( ) Imaging and Audio ( ) ASIC ( ) Sun Business
( ) Broadband Communications

Wireless:
(X) Chipset ( ) OMAP ( ) System Architecture (X) Mixed Signal/RF
( ) Emerging Markets ( ) Assembly/Test/Packaging ( ) Other:

3. What is the problem solved by your invention?

The conventional bandpass ΣΔ modulator suffers from high power consumption and limited resolution.

4. What is your solution to the problem?

To use a passive bandpass loop filter to run at a high sampling rate and low power for high resolution.

5. When was your solution first conceptually or mentally complete? Date: ___/___/___

6. What is the first tangible evidence of such completion?
Date: ___/___/___

7. What are the advantages of your solution?

Low power and high resolution

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PATENT DEPT

8. What is different about your solution, compared with other solutions to the same problem?

Ours is possive and other solutions are active

9. What TI products, processes, projects or operations currently implement your invention?

N/A

10. What is the date of the first implementation? ___

11. What record exists to prove this date?

Candence Database

12. Is there any future implementation planned? (Y/N) No
If so, please furnish the TI PART No. or project name:

13. Has the invention been published or disclosed to anyone outside of TI? (Y/N) No When? ___ If planned - when? ___ (Catalog, advertising, data book, application note, conference paper, magazine article, TI TJ, proposal document). Was there a nondisclosure agreement (NDA)? (Y/N)___

14. Has a TI product incorporating the invention been publicly introduced, quoted, sampled or shipped? (Y/N) No
When? ___ If planned -- when? ___.

15. Was the invention conceived or first implemented in the performance of a government contract or subcontract? (Y/N) No Contract #: ___

* THE INVENTION DESCRIBED BY THIS DISCLOSURE IS SUBMITTED PURSUANT TO MY EMPLOYMENT AGREEMENT WITH TEXAS INSTRUMENTS INCORPORATED OR A TI SUBSIDIARY (SPECIFY): *

Has this disclosure been previously sent to the Patent Department electronically (unsigned)? (Y/N) NO.

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City, State, Zip, and County

eMail: ______

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Witness 1:

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Date

This invention disclosure with any attachments was read and understood by me on ____/____/____.

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Witness 2:

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Date

A Passive Bandpass Sigma Delta Modulator

Feng Chen

Bandpass sigma delta modulators(SDMs) can be used to digitize a narrowband IF signal. In this disclosure, a passive bandpass sigma delta modulator is proposed and it is suitable for operation at high sampling rate and low voltage low power.

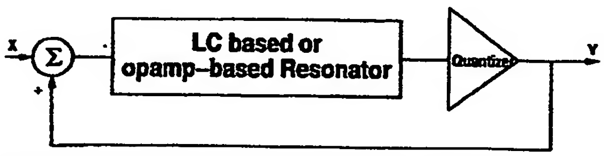


Fig.1: Prior art of bandpass sigma delta modulators

Prior Art

In prior art, bandpass sigma delta modulator is active and usually consists of operational amplifier(opamp)-based resonators in the loop filter or LC based. High power consumption and limited performance are the major limitations for the active approach.

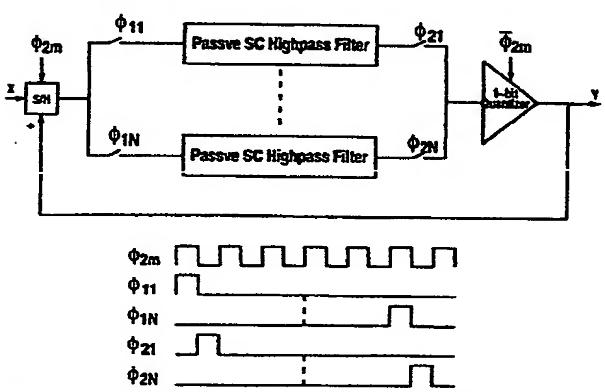


Fig.2: A passive bandpass sigma delta modulator

Proposed Architecture

The key idea here is to replace the active bandpass loop filter with a passive bandpass loop filter, such as N-path filter as shown in Fig. 2. which is the simplest implementation of passive bandpass filter. It can be expected that significant amount of power will be saved because no opamps are used. Even though placing N lowpass filter in parallel also generate a bandpass response, using highpass filter will results in more efficient hardware. As shown in the figure, each path contains a highpass filter which has a transfer function of $\alpha/1+(1-\alpha)z^{-1}$, (i=1,..,N). With a total number of N highpass filter placed in parallel, the final path filter has an overall transfer function of $\alpha/1+(1-\alpha)z^{-N}$ with its passbands centered around $Fs*i/2N$, where i=0,.... Due to the large loop gain intrinsic to any sigma delta loop, the mismatch of the loop filter will be suppressed by the loop gain.

SHaring the sample/hold(S/H) circuit among all paths will further reduce mismatch error along the path because it is difficult to match the S/H circuit in gain and phase at a high speed sampling rate with a high frequency IF input. However, with the high speed switching capability offered in deep submicron process, we can design a high speed a S/H circuit for sharing and convert the tones due to path mismatch to an overall gain or phase error. Therefore, special attention has to be paid to the S/H. Similarly, one single comparator is shared among all paths to remove gain and phase and offset error induced tones. Then a high speed comparator is needed.

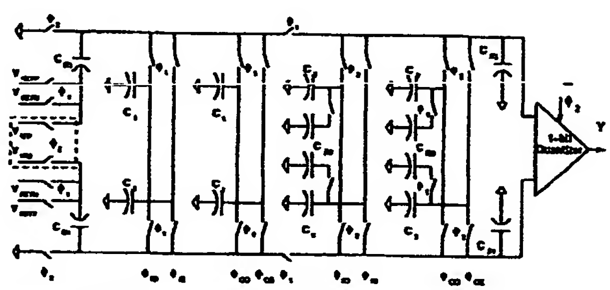


Fig.3: A SC implementation of a 4th-order passive SDM

Fig. 3 shows an example of two-path fourth-order passive bandpass sigma delta modulator implemented in fully differential switched capacitor circuit. With the number of paths equal to 2, the IF input frequency is limited to be around $Fs*i/4$. A shared sampling capacitor C_{RI} is switched at Fs. The internal switched capacitor circuit is controlled with either an even-indexed clock or an odd-indexed clock for the realization of a highpass switched capacitor filter. Then the two highpass filters are interleaved with control clock either labelled as I or Q to realize a transformation from highpass response to bandpass

response. Here the example given is only for fourth order implementation. However, higher order implementation can be done in a similar arrangement.

A variation of the scheme is that a mixing stage can be placed directly in front of the modulator to replace the input sampling cap, even though the same cap is still needed for the feedback DAC. In this way, the mixing stage has to supply a current-mode IF input to the modulator, instead of a voltage.

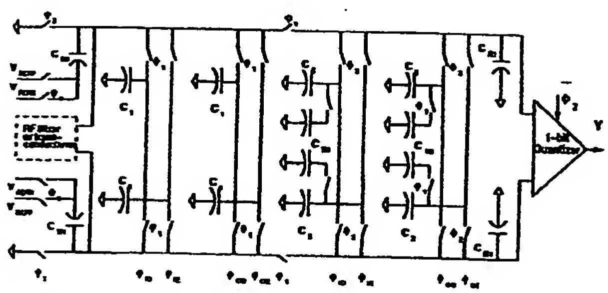


Fig.4: A 4th-order passive SDM with a built-in mixing stage

Simulation Results

A behavioral simulation is performed to verify the performance of the design example in two-path SC implementation. The circuit is designed to run at a clock rate of 104MHz and have an IF input at 26MHz. Fig. 5 shows the output spectrum of the forth-order passive bandpass sigma delta modulator. With a oversampling ratio of 256 and an equivalent bandwidth of 200KHz, a SNR of 80dB is achieved. A close-up plot of the inband spectrum is also shown.

Conclusions

A passive bandpass sigma delta modulator based on N-path high filter has been described. The key advantages of this architecture is (a) high sampling rate and high resolution, (b) low power because no power hungry opamps and (c) suppressed images with shared sample/hold and comparator. This architecture is suitable for the implementation in deep submicron process.

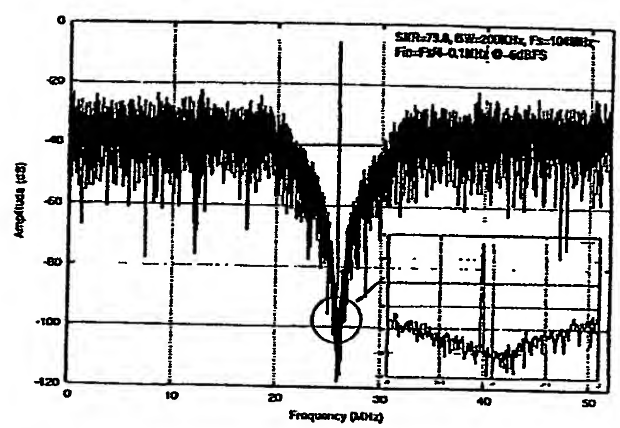
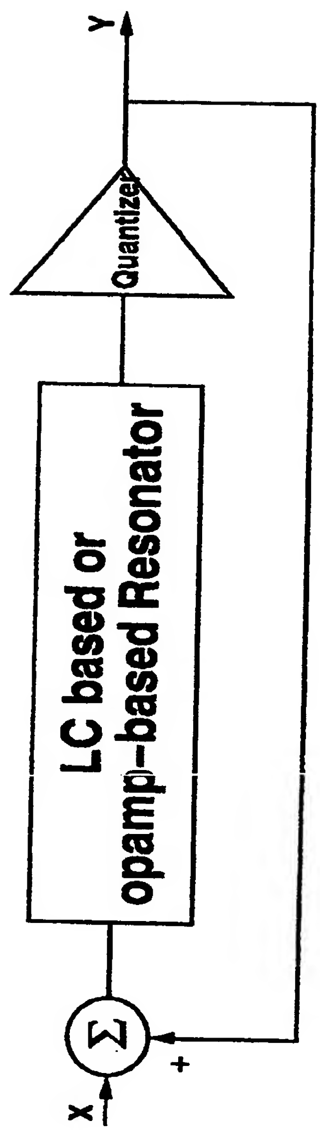


Fig.5: Output spectrum of passive bandpass SDM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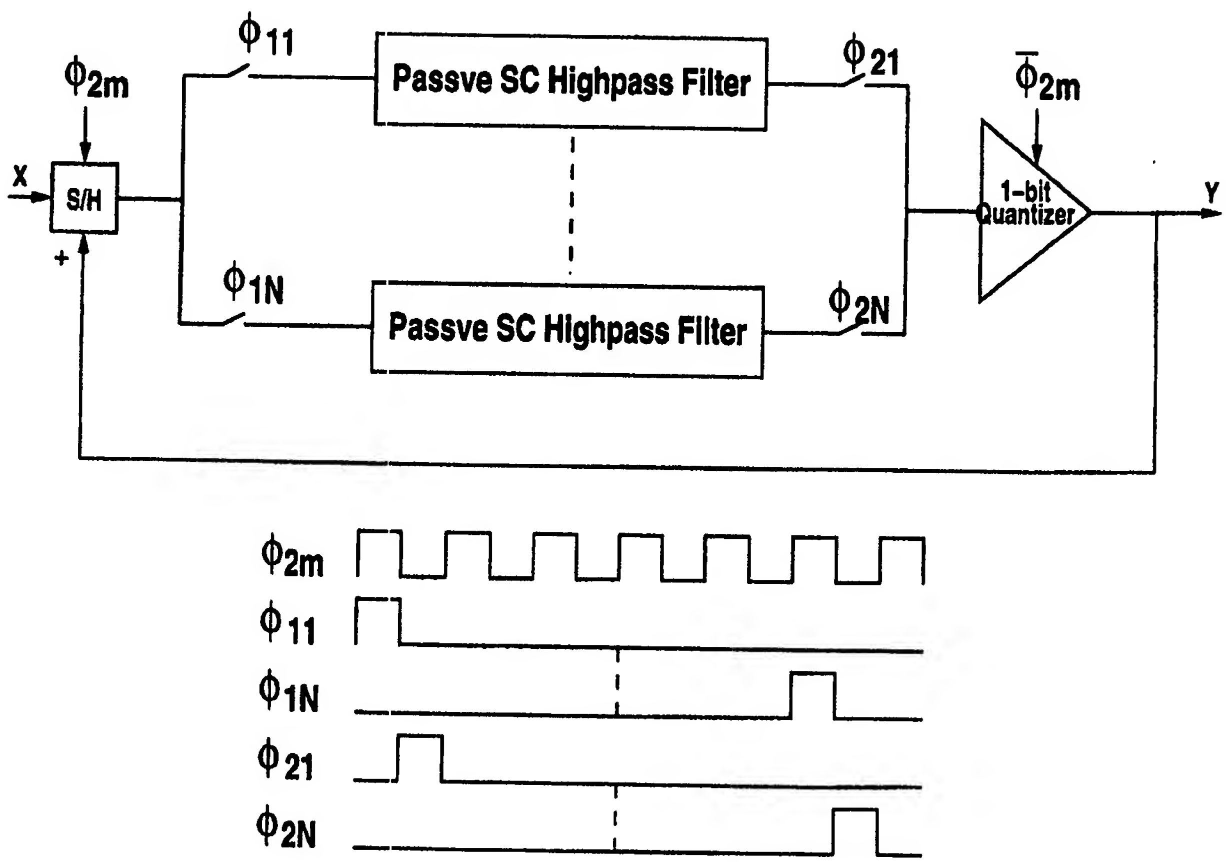
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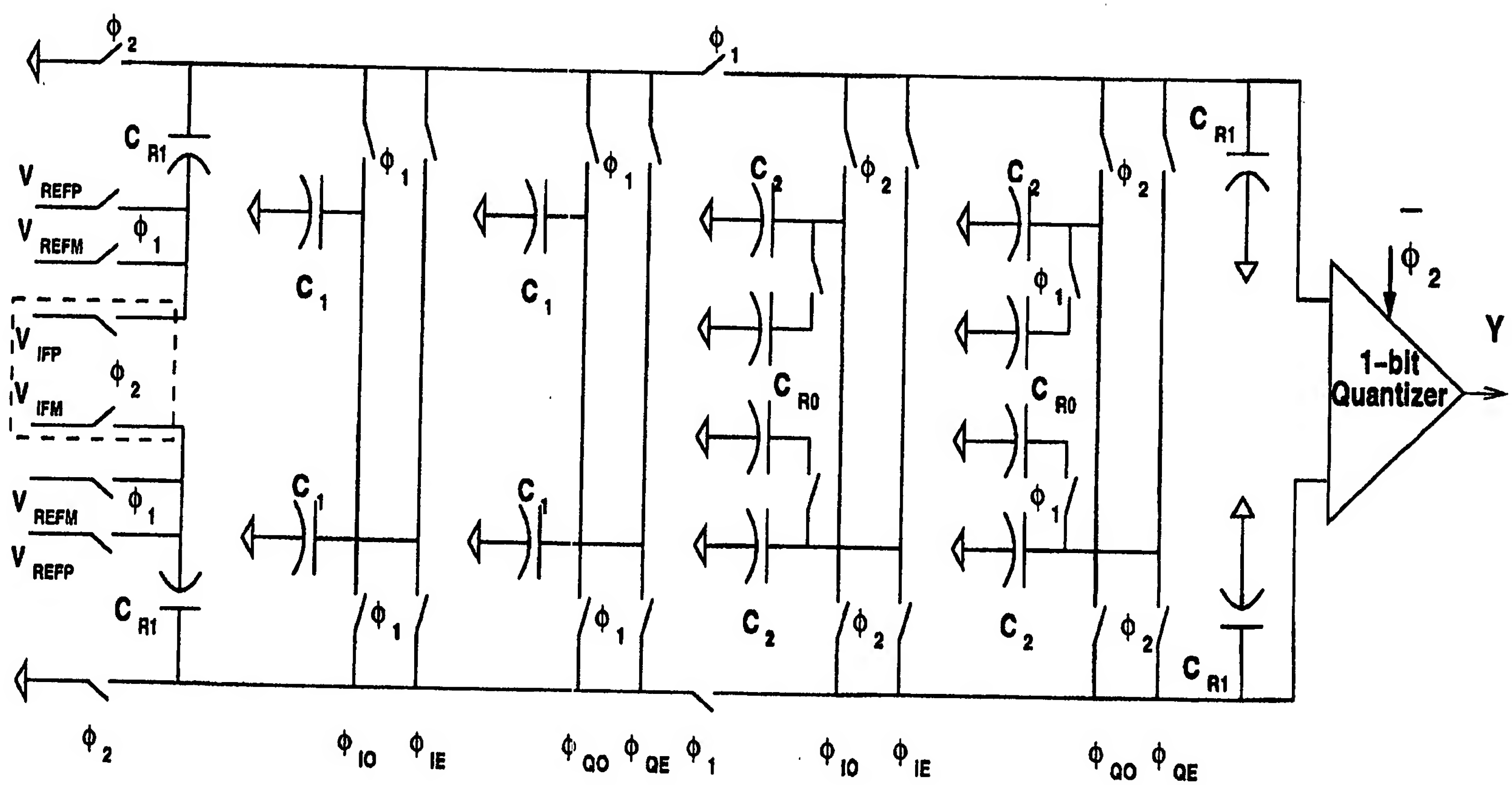
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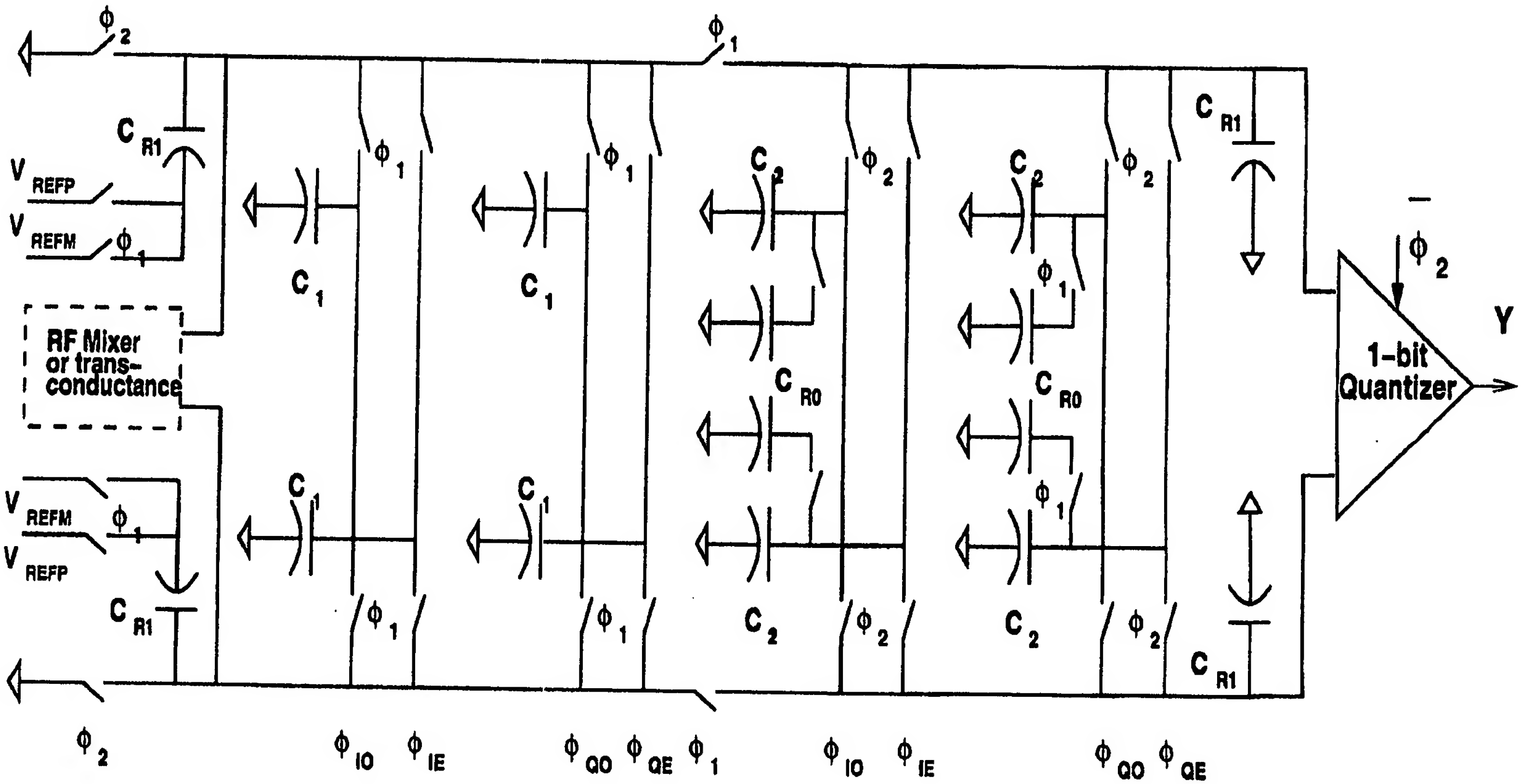

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